MODULAR CONTROL APPARATUS FOR A POWER IMPACT TOOL

FIELD OF INVENTION

This invention relates generally to the field of power impact tools and, more particularly, to a modular control apparatus for a power impact tool and more specifically to timing devices.

BACKGROUND OF INVENTION

Power impact tools (e.g., pneumatic, hydraulic, electric, etc.) are well known in the art. Power impact tools produce forces on a workpiece by the repeated impact of a motor-driven hammer on an anvil that is mechanically connected, directly or indirectly, to exert a force on the workpiece. Some power impact tools exert linear forces. Other power impact tools exert torque, which is a twisting force.

One difficulty in current power impact tools is that power may be applied too long to the workpiece. The accumulation of impacts on any already tightened workpiece may cause damage. Current power impact tools shut off when the operator manually enables shutting off. For example, in a pneumatic hand tool such as a torque wrench, the operator releases the trigger valve to shut off the supply of compressed air to the tool motor. The number of

impact forces delivered to the workpiece depends on the reflexes and attentiveness of the tool operator. During any delay, the workpiece may become overtorqued and damaged.

Accordingly, there is a need in the field of power impact tools for ways to provide more predictable amounts of torque ultimately applied to a workpiece. Additionally, there is a need for a control apparatus that will limit the time that a force of a power impact tool is applied to a workpiece.

SUMMARY OF INVENTION

The present invention provides an apparatus and method for use in controlling power impact tools.

An first general aspect of the invention provides a modular control apparatus comprising:

a modular structure;

at least one control valve; and

an adjustment mechanism for controlling at least one limit of the control valve.

A second general aspect of the invention provides a power impact tool comprising:

a housing;

an air motor contained within said housing; and

a modular, releasably-attachable, user-adjustable control apparatus.

A third general aspect of the invention provides a power impact tool comprising:

a housing;

an air motor contained within said housing, wherein said air motor provides a first torque output; and

a modular, releasably-attachable, user-adjustable control apparatus;

An fourth general aspect of the invention provides a power impact tool comprising:

a housing;

an air motor within said housing;

a workpiece adapter operatively attached to said air motor; and

a modular, releasably-attachable, user-adjustable control apparatus.

The foregoing and other features of the invention will be apparent from the following more particular description of various embodiments of the invention.

BRIEF DESCRIPTION of DRAWINGS

Some of the embodiments of this invention will be described in detail, with reference to the following figures, wherein like designations denote like members, wherein:

FIG. 1A depicts a cross-sectional view of an alternative embodiment of a power impact tool adapted to receive a modular, releasably-attachable control apparatus, in accordance with an embodiment of the present invention;

FIG. 1B depicts a cross-sectional view of an embodiment of a modular, releasably-attachable, user-adjustable, control apparatus, in accordance with an embodiment of the present invention;

FIG. 2 depicts a diagrammatic view of an embodiment of a modular, releasably-attachable, user-adjustable control apparatus, in accordance with an embodiment of the present invention;

FIGS. 3A-C depict a cross-sectional view of an embodiment of a poppit valve of an embodiment of a modular, releasably-attachable control apparatus, the valve shown in three different operational positions in accordance with an embodiment of the present invention;

FIG. 4A depicts a cross-sectional view of an embodiment of an adapter plate in accordance with an embodiment of the present invention; and

FIG. 4B depicts a cross-sectional view of an alternative embodiment of an adapter

plate in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Although certain embodiments of the present invention will be shown and described in detail, it should be understood that various changes and modifications may be made without departing from the scope of the appended claims. The scope of the present invention will in no way be limited to the number of constituting components, the materials thereof, the shapes thereof, the relative arrangement thereof, etc., and are disclosed simply as an example of an embodiment. Although the drawings are intended to illustrate the present invention, the drawings are not necessarily drawn to scale.

The modular control apparatus is used with, or as part of, a power impact tool and allows for time-limiting the torque output. Power impact tools can include various power (e.g., pneumatic, hydraulic, electric, etc.) impact tools. This modular control apparatus, when used with a power impact tool, for example with a pneumatic impact tool, provides a fixed duration of torque from the air motor within the tool, to a workpiece, such as a nut or bolt. A motor, as defined and used herein, is any device for converting a first flow of energy into kinetic energy. For example, an air motor converts the energy of a flow of expanding compressed gas into the rotational motion of a mechanical drive shaft. For another example, an electric motor converts a flow of electricity into the rotational motion of a mechanical

drive shaft. For yet another example, the drive piston and valves of a jack hammer form a motor to convert the energy of an expanding compressed fluid into linear motion of a mechanical drive shaft. For a final example, a hydraulic motor converts the kinetic energy of a flowing, slightly compressible fluid (hydraulic fluid) into the rotational motion of a mechanical drive shaft. The drive shaft, in each embodiment, is rotated by the motor, and tools, for operating on work pieces (workpiece adapters) are mechanically connected directly or indirectly between the drive shaft and the work piece.

Referring now to FIG. 1A, an embodiment of a power impact tool 10 is shown in a vertical section through the centerline of the tool 10. The tool 10 has a handle 12 containing a channel 50 for receiving a compressible fluid through a port 52 at the base of the handle 12. A channel is a confined path for the flow of a compressible fluid. Channels may be pipes, hoses, bores formed in a block of material, or similar flow constraints.

A compressible fluid, as defined and used herein, is a fluid with a bulk modulus that is less than the bulk modulus of water. Compressible fluids with low bulk moduli transfer energy by converting the potential energy of their compressed state into the kinetic energy of an expanding fluid and then into the kinetic energy of a motor rotor. Elemental gases, such

as helium and nitrogen, and mixed gases such as air, are compressible fluids with low bulk moduli. Slightly compressible fluids have high bulk moduli and are used for force transmission. Hydraulic fluids, for example, typically have higher bulk moduli. Either type of compressible fluid can transfer energy into a motor.

The port 52 is equipped with a fitting 54 for connecting to a supply of compressed fluid. A supply of compressible fluid may be, for example, a compressed air hose such as is used in an auto repair shop to power pneumatic tools. Within the channel 50 is a manually operated valve 62, shown in FIG. 1 as a trigger valve 62, which enables the tool-user to regulate the flow of compressible fluid through the channel 50. By depressing the trigger 60, the valve 62 is opened, thereby channeling the compressible fluid toward a motor 14 of the tool 10. The channel 50 extends to a backplate 70 of the tool where the channel 50 terminates at a port 56 sized and shaped to receive (see FIG. 1B) a corresponding port 250 to a first channel 202 in a modular control apparatus 600. Thus, the first channel 202 is the input channel.

A modular control apparatus 600 is a first apparatus that controls at least one function of at least one second apparatus. Furthermore, a modular control apparatus 600 is modular

in that it may be manipulated as a single physical unit (a module). The module comprises a generally solid block, or body, within which are formed the mechanisms which implement control functions. The body may be created from a single block or may be built up from a plurality of ub-blocks. The modular control apparatus 600 may be manipulated into a relationship with a second apparatus in which interaction between the modular control apparatus 600 and a second apparatus results in a change in the operation of the second apparatus. For some examples in the field of pneumatics, a modular control apparatus 600 may shut off air flow to a tool 10 (a second apparatus) after a user-selected time, may oscillate the direction of air flow, as in a jack hammer, or may change the pressure of the air entering the second apparatus.

The modular control apparatus 600 is configured to be releasably attachable to the tool 10. The apparatus is releasably attachable when the connections between the modular control apparatus 600 and the tool 10 can be opened and closed by the tool user. The connectors may be bolts, clamps, latches, or similar devices known in the art. In an embodiment, the connections can all be opened or all be closed by a single motion of the user's hand.

Also located on the backplate 70 is a port 58 sized and shaped to receive the compressed fluid which is discharged from (see FIG. 1B) an output port 252 of a second channel 212 of the modular control apparatus 600. The second channel is the output channel. The backplate 70 may be, for example, the backplate 70 of a Model 749 pneumatic torque wrench made by Chicago Pneumatic Tool. In an embodiment, the backplate 70 has a cylindrical protrusion 74, perhaps accommodating a motor bearing within, which is used an alignment mechanism for aligning the modular control apparatus 600 to the tool 10.

Referring to FIGS. 1A and 1B, in an embodiment, the modular control apparatus 600 has a structure 80 containing a cavity 78 sized and shaped to slidingly receive the cylindrical protrusion 74 of the backplate 70. The purpose In an embodiment, the backplate may further comprise an alignment dowel 72 which is sized and shaped to be slidingly received into a cavity 76 in the modular control apparatus 600. In an alternate embodiment, the cavities 76 and 78 may be in the backplate 70 and the cylindrical protrusion 74 and alignment dowel 72 may be part of the modular control apparatus 600. In another alternate embodiment, the backplate 70 has at least one alignment mechanism and at least one cavity, with at least one corresponding cavity and at least one corresponding alignment mechanism integrated into the modular control apparatus 600.

In alternative embodiments, the backplate 70 may be an adapter 900 which provides an interface between a tool 10 and the modular control apparatus 600. In such retrofit cases, an adapter 900 may be designed for each uniquely designed tool. On the modular control apparatus-receiving side of the adapter 900, at least a portion of the adapter may be configured like the backplate 70 of a tool 10 for which the modular control apparatus 600 was originally designed. Remaining portions of the adapter 900 provide two channels for compressible fluids: a first adapter channel 910 between the compressible fluid supply and the input port 250 of the modular control apparatus 600 and a second adapter channel 920 between the discharge port 252 of the modular control apparatus 600 and the tool 10 motor 14. The adapter 900 also provides sufficient structure 70 and attachment mechanisms 80 for securing the adapter 900 to the tool 10 and to the modular control apparatus 600.

FIG. 2 shows an embodiment of a modular control apparatus 600 in a semi-diagrammatic view. An embodiment of the modular control apparatus 600 contains an automatic shutoff valve 100 that shuts off the flow 214 of compressible fluid to the motor at a user-adjustable time after the beginning of flow of compressible fluid through the modular control apparatus 600. In the embodiment of FIG. 2, compressible fluid flows through an input port 250 into a first channel 202, through the biased-open valve 100, into and through a

second channel 212, and is discharged from port 252 into the inlet 58 (FIG. 1A) of the motor of the tool.

The valve 100 comprises a valve chamber 120, a valve body 114, a biasing mechanism 116, and seals 110 and 118. The valve chamber 120 has ports 150-158 to a plurality of channels 202, 204, 208, 210, and 212. The valve body 114 fits slidingly within the valve chamber 120. In the embodiment shown in FIG. 2, the valve body 114 has one degree of freedom of translational motion. In this embodiment, the valve body 114 may also have one degree of freedom of rotational motion because the valve body 114 has rotational symmetry about its long axis. The rotational symmetry of the valve body 114 obviates the need for the valve body 114 to maintain a specific rotational orientation within the valve chamber 120 during operation. The degree of freedom of motion which opens and closes the valve 100 is the operational degree of freedom. In alternate embodiments, the valve body 114 and valve chamber 120 may not be rotationally symmetric. In other alternate embodiments, a valve 100 operates by sliding rotationally instead of translationally. Those having skill in the art will realize the advantages of minimizing the mass of the valve body 114 within the other design constraints.

The biasing mechanism 116 is any mechanism or combination of mechanisms that exerts force on the valve body 114 in one direction aligned to the operational degree of freedom of motion of the valve body 114 and over at least a portion of the range of valve body 114 motion. The biasing mechanism 116 is typically a spring, but may be a compressible fluid or other elastic members.

In the embodiment of FIG. 2, a first end of the valve body 114 has a poppit portion 108. The poppit portion 108 is a rotationally symmetric extension of the valve body 114 with a uniform and smaller diameter than the maximum diameter of the valve body 114. The poppit portion 108 has a predetermined length 112. When the valve body 114 is in its biased position, the poppit portion 108 is received slidingly into a correspondingly narrowed portion 102 of the valve chamber 120. The narrowed portion 102 of the valve chamber 120 may made longer than the poppit portion 108 of the valve body 114, in order to form a chamber 104 for receiving compressible fluid from the reservoir 400. The reservoir 400 is a cavity for accumulating compressible fluid. The receiving chamber (or actuating chamber) 104 may be considered a further extension of the valve chamber 120. In an alternate embodiment, the receiving chamber 104 may be wider than the diameter of the poppit portion 108 of the valve body 114. In another embodiment, the receiving chamber 104 may

be an extension of the fifth channel 208 which connects the reservoir 400 to the poppit end, or biased end, of the valve chamber 120. In yet another embodiment, there is no discrete receiving chamber 104, as the narrow poppit portion of the valve chamber 120 is a port directly into the reservoir 400. The end surface 106 of the poppit portion 108 is exposed to the pressure of compressible fluid which may be received in the receiving chamber 104. The pressure of the fluid in the reservoir 400 exerts a force on the end surface 106 of the poppit portion 108 of the valve body 114 and, thereby, on the valve body 114 itself. The receiving chamber 104 may be regarded as an expandable and contractible chamber having one moveable wall, the moveable wall being the end surface 106 of the poppit portion 108 of the valve body 114. In an embodiment wherein the valve operates by rotation, the actuating chamber 104 may be completely separate from the main valve chamber.

The pressure of the compressible fluid at a given time in the reservoir 400 depends, in the first instance, on the rate of flow into the reservoir 400. The rate of flow is controlled by the setting of a needle valve 300. The needle valve 300 comprises a needle valve seat 304 within a third channel 206, a needle valve body 302, and a user-accessible extension of the needle valve 306. The needle valve seat 304 comprises a channel portion tapered concentric to the needle valve body 302, a shaft bearing to hold the shaft of the needle valve body 302,

and a seal to prevent leakage through the shaft bearing. The third channel is the reservoir input channel. In an embodiment, the threaded extension 306 is screwed into a threaded portion 308 of the third channel 206. In an alternate embodiment, the extension 306 is provided with a locking mechanism, for example: a set screw, to prevent vibrations caused by operating the tool to change the setting. The user selects the amount of time between the introduction of compressible fluid into port 250 (as by squeezing the trigger 60 (FIG. 1A)), and the closing of the poppit valve 100 by adjusting the needle valve 300. The higher the rate of flow, the faster the reservoir 400 reaches a pressure sufficient to close the valve 100.

Referring now to FIGS. 3A-C, at a point in the operating cycle where the pressure of the compressible fluid in the receiving chamber 104 exerts more force on the valve body 114 than the biasing mechanism 116, the valve body 114 begins to move against the bias (FIG. 3A). At or near the boundary between the poppit-receiving portion 102 of the valve chamber 120 and the remaining valve chamber 120, the valve chamber has a seal 110. The seal 110 prevents pressure leakage from the receiving chamber 104 into the remaining valve chamber 120 while the valve body 114 moves against the bias for the predetermined length 112 of the poppit portion 108. The valve body 114 moves against the bias by the force exerted on the end surface 106 of the poppit portion 108 by the compressible fluid from the reservoir 400 as

it reaches the receiving chamber 104. AS shown in FIG. 3B, when the valve body 114 moves against the bias more than the predetermined length 112 of the poppit portion 108, the seal 110 is avoided, exposing the entire area determined by the cross-section of the valve body 114 to the pressure from the reservoir 400 through receiving chamber 104. The equal pressure on the increased area creates a steep increase in the anti-bias force, thereby slamming the valve body 114 into the anti-biased (closed) position (FIG. 3C). The valve body has a channel through which the compressible fluid flows 214 from the first channel 202 to the second channel 212 when the valve 100 is open (FIG. 3A). This channel is made wider than the valve chamber ports 150 and 158 (FIG. 2) for the first channel 202 and second channel 212 so that flow 214 through the valve 100 is unaffected by the initial anti-bias motion for the predetermined length 112 of the poppit portion 108 (FIGS. 3A-B). Thus, from the perspective of the fluid flow 214 through the valve 100, nothing happens until the valve body 114 slams shut (closes) (FIG. 3C).

When the valve 100 closes (FIG. 3C), two ports 152 and 156 (FIG. 2) are exposed (opened) in the portion of the valve chamber 120 at the biased end of the valve chamber 120. The biased end of the valve chamber 120 is the end of the valve chamber 120 where the valve body 114 rests when the force exerted by the biasing mechanism 116 predominates, as

shown in FIG. 3A. When the valve body 114 was in the biased position, or within a predetermined poppit portion 108 length 112 of the biased position, two ports 152 and 156 (FIG. 2) where closed by surfaces of the valve body 114. When the valve body 114 moves to the anti-biased position, as shown in FIG. 3C, the two ports 152 and 156 open. One of these ports 152 receives compressible fluid from a fourth channel 204. The fourth channel 204 connects the first channel 202 (the fluid input channel, FIG. 2) to the valve chamber 120 when the valve body 114 is in the anti-biased position (FIG. 3C). The compressible fluid from the fourth channel 204 provides sufficient pressure to latch the valve 100 in the anti-biased position. The other port 156 in the valve chamber 120 which is opened by the valve body 114 moving to the anti-biased position is a vent port 156. The vent port 156 discharges 222 and 224 compressed fluid into the sixth channel 210. The sixth channel 210 leads to open air, in the case of a pneumatic device, or to a return line in the case of compressible fluids not normally released into the atmosphere, such as hydraulic fluid or dry nitrogen. In any embodiment, the sixth channel 210 drains compressible fluid 222 and 224 and its pressure from the valve chamber 120 and reservoir 400 (FIG. 2) through fifth channel 208 and receiving chamber 104. The sixth channel 210 is sufficiently narrow, as compared with the fourth channel 204 (the latching channel), that the valve 100 will remain latched for as long as compressible fluid is available from the fourth channel 204 by way of the first

channel 202. However, when the supply of compressible fluid is shut off, as by releasing the trigger 60 (FIG. 1A) in the present embodiment, the vent 210 dissipates 222 and 224 the pressure from the valve chamber 120 and reservoir 400, allowing the biasing force on the valve body 114 to once again predominate and move the valve body 114 back to its biased position (FIG. 3A).

As shown in FIGS. 3A-C, the biasing mechanism 116 may be a spring. At the anti-biased end of the valve chamber 120, a ring seal 118 provides a bumper for the valve body 114 as it closes. In an embodiment, the ring seal 118 may also aid in sealing the junction between a part of the modular control apparatus 600 (FIG. 1B) containing most of the valve chamber 120, and a second part forming the anti-biased end of the valve chamber 120. In the embodiment of FIGS. 3A-C, the anti-biased end of the valve body 114 has a recess for receiving one end of a coil spring 116. The recess aids in maintaining the alignment of the spring 116 during operation.

Referring back to FIG. 2, the first channel 202 also has a port 160 into a third channel 206 and another port 162 into a fourth channel 204. The third channel 206 provides restricted flow of compressible fluid from the first channel 202 to the reservoir 400. In the

embodiment of FIG. 2, the flow restriction is a variable flow restriction wherein the amount of flow restriction is determined by the position of a user-adjustable needle valve 300. Compressible fluid from the third channel 206 flows through the flow restriction into a reservoir 400. The reservoir 400 accumulates compressible fluid, increasing the pressure within the reservoir 400. The reservoir 400 has an outlet through a fifth channel 208 which leads to the receiving chamber 104 portion of the valve chamber 120. The pressure in the receiving chamber 104 exerts a force on an end surface 106 of the poppit portion 108 of the valve body 114. The pressure-derived force opposes the biasing force on the valve body 114.

The rate at which the reservoir fills with compressible fluid is determined by the flow restriction. The nearer the needle valve 300 is to being closed, the longer it takes for the reservoir 400 to accumulate enough fluid to create enough pressure to exert enough force to overcome the biasing force on the valve body 114. Thus the needle valve 300 position determines the amount of time between the beginning of fluid inflow (when the operator squeezes the trigger 60 (FIG. 1A) on a pneumatic torque wrench, for example) and the latching of the valve 100, which shuts off the motor 14 of the tool 10. In addition to minimizing wasted energy and avoiding over-torque conditions by time-limiting tool

operation, the needle valve 300 adjustment can be used to compensate for the inevitable changes in the properties of the valve spring 116 over the life of the tool 10. Likewise, the needle valve 300 can be adjusted to provide different times for different work situations. For example, tightening an eight-inch-long bolt would take more time than tightening a one-inch-long bolt.

Referring again to FIGS. 1A and 1B, the valve 100, needle valve 300, and channels 203, 204, 206, 208, 210, and 212 are contained within a modular structure 80 designed to be aligned with and releasably attached to a tool 10. The alignment mechanisms 72, 74, 76, , and 78 comprise passive means to ensure that the input port 250 and discharge port 252 of the modular control apparatus 600 mate sealingly with the fluid supply port 56 and the motor inlet port 58 of the tool 10, respectively. In an embodiment, the backplate 70 of the tool 10 has a cylindrical extension 74 that fits into a corresponding recess 78 in the modular control apparatus 600. The backplate 70 is further equipped with at least one asymmetrically arranged rod 72 corresponding to at least one hole 76 in the modular control apparatus 600. The rods 72 are arranged asymmetrically so that there is only one orientation of the modular control apparatus 600 that will allow the apparatus 600 to be received onto the tool 10. That orientation is the orientation at which the ports of the apparatus 250 and 252 and the tool will

line up properly. The attachment mechanism may be as simple as a bolt through the modular control apparatus into a threaded hole in the tool. Those skilled in the art of tool manufacture will be aware of many different ways of making the attachment. The requirements for the attachment mechanism are that it create a seal against leakage of the compressible fluid and that it be reusable.

In a particular embodiment, a modular control apparatus 600 is integrated with a handle 12 comprising a trigger valve 62 and 60 and associated channel 50, port 52, and fitting 54. In this embodiment, the motor 14 and elements of a drive train from a drive shaft of the motor 14 to an output fitting are modular and releasably attach to the integrated handle 12 and modular control apparatus 600. The advantage of this embodiment is that all of the elements controlling the flow of energy to the motor 14 are in one module.

Referring to FIG. 1C, the body of the an embodiment of modular control apparatus 600 may be manufactured from two or more blocks (also called parts or sub-blocks) 82 and 84. In an embodiment, the first block 84 is machined to contain the valve chamber 120 (FIG. 2), reservoir 400, the alignment holes 76 and 78, attachment mechanisms, the input and discharge ports 250 and 252, and all channels except the third channel 206,. All of the

features of the first block 84 can be formed by drilling and machining. The second block 82 contains the third channel 206 and the needle valve 300. The third channel 206 may be formed by drilling and machining. In assembly, the spring 116 and bumper seal 118 are inserted before the valve body 114, and an annular chamber end 180 with the poppit seal 110 after the valve body 114. Annular chamber end 180 forms the receiving chamber 104 and the valve chamber extension 102. Installation of the needle valve 300 requires at least one seal (not shown). Assembling the two blocks 82 and 84 together closes the valve chamber 120 and reservoir 400. The blocks 82 and 84 may be bolted together or affixed by permanent means, such as welding. A releasable assembly (bolts) is generally preferred, as it enables maintenance and refurbishment of the valve 100.

While this invention has been described in conjunction with the specific embodiments outlined above, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, the embodiments of the invention as set forth above are intended to be illustrative, not limiting. Various changes may be made without departing from the spirit and scope of the invention as defined in the following claims.